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Rational Establishment of Air Quality Standards

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This paper attempts to apply two principles of rationality—efficiency and equity—to the establishment of air quality standards for total suspended particulates in the USA. It is argued that standard setting should embrace either the use of some cost-benefit-risk criterion, or some concept of equity whereby risks are not reduced below levels judged to be acceptable elsewhere. There is often a trade-off to be made between these principles of efficiency and equity and that both cannot be pursued in tandem. In other words, the cost of fairness is more deaths in total than there need be at a particular level of expenditure.

The concept of the "margin of safety" is also discussed, and we conclude that, as currently defined, it is of doubtful relevance in either the context of efficiency or of equity.

Finally, and using evidence from other studies, we conclude that there are much more cost-effective ways of using scarce resources to save lives (e.g., in health care and in road safety) than pursuing the primary standards for TSP laid down by the United States Environmental Protection Agency in light of the U.S. Clean Air Act Amendments of 1970 and 1977.

Introduction

The issue addressed in this paper is whether the primary standard laid down by the United States Environmental Protection Agency (EPA) in light of the U.S. Clean Air Act amendments of 1970 and 1977 has a foundation in what we term "rational" approaches to standard setting. The standards set for total suspended particulates (TSP) were 75 $\mu g/m^3$ annual geometric mean of the 24 hr averages and 260 $\mu g/m^3$ average 24 hr measure. In addition, the concept of a margin of safety was introduced, although in practice it was left to the administrator of the EPA to determine what constituted a "reasonable" margin of safety. It is argued that standard setting should embrace either the use of some cost-benefit-risk criterion, or some concept of equity whereby risks are not reduced below levels judged to be acceptable elsewhere. We judge that neither paradigm has been used in setting the primary particulate standard and that, as a consequence, that standard is currently too severe in terms of the burdens it imposes on those who bear the cost (ultimately, as we suggest, the American people) for the benefits it can be argued to achieve.

In stressing the role of the EPA Administrator in protecting public health and in seeking to ensure that he is not impeded by tactics designed to prevent that task being fulfilled, the House of Representatives has dismissed the relevance of economic considerations (*1*). In this, it reflects the entire history of the Federal Act, since, even in its initial passage through Congress, numerous commentators noted what has been called (*2*) the "careful excising of almost all references in the Act to considerations of economic feasibility." Despite this, there has been relaxation of the National Ambient Air Quality Standards in respect of vinyl chloride, a pollutant with almost certainly no lower threshold (i.e., a level below which no health effects are caused), because of the impossibility faced by the industry in meeting the implied zero emissions requirement with known

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or immediately foreseeable technology. Instead, EPA set a nonzero emission limit. Thus, faced with the extreme consequences of following the letter of the Clean Air Act, the EPA did allow some consideration of the costs of such action and therefore of questions of efficiency.

The Philosophy of Rational Standard Setting

This paper considers the extent to which the approach adopted in the United States for the promulgation of primary standards for total suspended particulate (TSP) matter can be considered to be based on rational foundations. We offer two concepts of rationality. The first states that an environmental standard is rational if it is not possible to alter it in such a way that society's health risks are reduced without changing the amount of money spent on reducing those risks. This condition is met only if an extra dollar of expenditure on improved conditions achieves the same health benefit regardless of where it is spent. This is the "efficiency" concept of rationality. The second concept of rationality is defined in terms of "acceptable" risk. This is formulated differently according to which school of thought one acknowledges. One would argue (*3*) that a risk is acceptable in one sphere of activity if it is already accepted in some other sphere of activity, or, of course, if higher levels of risk are accepted in the alternative activity. Another view of acceptable risk suggests that the degree of acceptability varies with the benefit expected from the risk activity in question. On this basis, an acceptable risk becomes one in which the benefits exceed the costs of the risk of the project as seen by the person perceiving the risk. In this respect, the approach is akin to the efficiency definition of rational approaches to standard setting (*4*).

The pursuit of efficiency in the setting of standards leads logically to the use of cost-benefit (or benefit-cost) analysis. To find the degree of acceptable risk on the efficiency approach, we must compare the benefits obtained by the lowering of risk levels (for example through legislation) and the costs of achieving those risk reductions. A risk would be acceptable when the benefits of reducing it further were less than the costs of achieving the reduction. Cost has necessarily to be thought of as "opportunity cost," i.e., the value of the benefit we go without by choosing to spend the money in one way rather than another. The opportunity cost of setting environmental standards without reference to efficiency criteria can therefore be forgone benefits which actually exceed the benefits obtained from the environmental standard.

Equity is a term which has a variety of meanings in different contexts, but its underlying concern is with who gains and who loses. In the context of setting environmental standards, the pursuit of equity would imply that people should, in some sense, be treated fairly or equally.

To enable evaluation of environmental standards on equity grounds, it is necessary to have some yardstick against which to judge the results—some standard of "fairness." Many of the recommendations on methods of standard setting which are to be found in the scientific literature on risk analysis may be interpreted in the light of the pursuit of equity. One such, the "acceptable risk" method, has, as its basis, a concern to equalize the risks suffered by different people from different causes and to set this level at one which is "generally acceptable" to society. In furtherance of this argument several authors (*3, 5-11*) have tabulated estimates of risks associated with work, recreation and everyday living, usually in terms of fatality rates or occasionally accidents or morbidity incidence rates. Whether such studies accurately encompass the true meaning of the concept of risk is a subject of some debate (*12*).

There will normally be a trade-off between efficiency and equity, i.e., from a given situation, a move toward greater equity is likely to lead to greater inefficiency, and a more efficient move will normally prove less equitable. But how can this choice be made? Essentially, equity, efficiency and the choice between them involve value judgments on the part of policy makers. It is possible to choose an efficient solution or an equitable solution or some mix of the two, but the choice depends on the relative weights to be attached to equity and efficiency, a value-laden choice which nonetheless cannot be avoided. Because of the logical necessity of choosing weights, economists are concerned to spell out the implications of those choices.

Equity and the Particulate Primary Standard

This section argues that the concept of equity as expounded in the previous section is not embraced by the procedures used for implementing the primary particulate standard. First, we would suggest that the concept of a margin of safety does not readily fit into an equity-based framework. Second, "acceptable risk" involves two precepts. On the one hand, there is the assumption that the concern is to equalize risks faced by different people, a concern the Act shares. On the other hand, there is the assumption that there exists some nonzero level of risk at which concern ceases and which is therefore acceptable. This view is certainly not embodied in the Act, for it seeks to reduce to zero the probability of any air pollution-related ill-health occurring. Yet, the attempt to eliminate risk completely from our lives is stultifying of enterprise and ultimately self-defeating (*13*). Nor indeed is the idea of reducing this probability to zero embodied in other health protecting legislation in the United States. For example, a recent court ruling (*14*) with respect to occupational health and the use of benzene has made it clear that in some circumstances a nonzero level of risk of benzene-related ill health is acceptable.

It could be that the events associated with exposure to air pollution are so dreadful that, even when combined with an extremely low probability of occurrence, they constitute a risk which is above that normally acceptable. But this is implausible. There are the beginnings of an understanding of those factors which affect individuals' perception of risk and on this evidence there are not strong grounds for expecting the adverse reaction to the events associated with air pollution to be especially marked. Thus, the most important characteristics affecting this severity are voluntariness, controllability, familiarity, immediacy and predictability (*15*). Certainly the risks are involuntary, but they have been with us a long time and score reasonably well for controllability, familiarity and knowability, while most of the risks which now exist lie in the future, after prolonged exposure to pollution.

We observed that the pursuits of equity and efficiency each have a cost in terms of each other. If an efficiency-based approach is adopted, there is a cost in the sense that some people may be treated unfairly relative to others. The pursuit of equity also has a cost in terms of efficiency. No matter what level of risk is chosen on equity grounds, any given level of expenditure would prevent more premature deaths if it were spent according to efficiency guidelines. The cost of fairness is more deaths in total than there need be at that level of expenditure. It is but a small step from recognizing the costs of pursuing zero risk objectives to a rather fuller and more systematic consideration of efficiency.

Even if the Clean Air Act shunned economic considerations in principle, in practice it is left to the administrator of the EPA to determine what constitutes a "reasonable" margin of safety. The only level of particulate emission which could guarantee zero risk is one at which the standard is set in such a way that it exceeds the best judgment of the threshold level by some factor which accounts for both any statistical error in the identification of the threshold, and any, as yet, unidentified risks from ambient concentrations greater than zero and less than the established threshold level.

Following the work of Holland and his colleagues (*16*), we observe that, translated to US measurement techniques, the level at which health effects can be attributed to TSP (in the presence of SO_2) is some 240 μg/m^3. Between 130 μg/m^3 and 240 μg/m^3 the effects of TSP are not discernible in the sense that they cannot be separated out from other influences such as weather. At levels below 130 μg/m^3 no effects at all can be demonstrated. Effectively, then, a 130 μg/m^3 standard would give the zero risk results which, we argue, are dictated by the Clean Air Act as it now stands, even if we find it impossible to accept that a zero risk level of effect is a rational standard.

What meaning, therefore, is attached to the margin of safety in this context? As noted above, it has little relevance in an equity-based standard which has an "odd" equity objective, namely, zero risk. That objective is odd because acceptable risk, in our view, implies acceptance of some positive risk levels. However, if we pursue the zero risk requirement, we see that the 130 μg/m^3 threshold already defines the lower bound of the "possible effects" level of TSP. That is, it already embraces any statistical error in the data and actually guarantees zero risk on the best scientific evidence available. The problem then is that to go lower than 130 μg/m^3 entails a concept of the margin of safety which becomes untenable on equity grounds (and, as we shall argue, on efficiency grounds as well). For it is effectively "overkill." It does not reduce risks any further. To argue that it insures against any unanticipated risks as well is to countenance complete arbitrariness in setting standards—any number would in fact meet the requirement, as long as it is below 130 μg/m^3. Indeed, if one wants an absolute, unqualified guarantee of zero risk, the standard would be set at zero. Yet a zero standard does not exist because it is technologically and economically infeasible.

In short, it is difficult to see what the margin of safety has to do with an equity-based concept of a standard since equity demands that the risks associated with the eventual compliance with the standards be the same as those risks elsewhere (and, as noted above, that efficiency be ignored). Yet nowhere else is zero regarded as the acceptable level of risk. We conclude that the margin of safety concept implicit in the 75 μg/m³ standard is inconsistent with the concept of an equity based standard.

Last, one could ask whether the ratio of TSP threshold levels to standard levels compares with such ratios used elsewhere. For example, using the judgments of Holland and his colleagues (*16*), the ratio would be about 1.75:1. In radiation exposure, various ratios are used. If exposed to 5 rems in any one year (rem = a unit of exposure to radiation), it is widely accepted that the risk of dying at some time in a lifetime would be 1 in 2000. Spread over a working lifetime of, say 40 years, this is a risk of 1 in 80,000 of dying in a given year from the effects of nonnatural radiation (*17*). UK practice is to set the maximum dosage to a worker at 1 rem, so that the margin of safety is 5:1. This would appear favorable when compared to the TSP ratio. Two comments can be made. First, if the same ratio were used for TSP in the USA, the primary standard would have to be set at 26 μg/m³, which places us even further into the realms of overkill in terms of the most reliable information available. Second, the cost of achieving the 5:1 ratio in radiation standards is not very high, given continuous monitoring and the ability to move exposed workers to less radioactive areas for a while.

Comparison of the margin of safety in terms of a ratio of standard to threshold level in comparison with other such ratios could argulably be said to meet the "equity" requirement. The example above suggests that such a comparison results in a greater inconsistency for the TSP standard and also hints that there is one overriding factor in determining a margin of safety which must be taken account of—namely, the cost of achieving it.

Data limitations are such that it is not possible to estimate with accuracy what the costs of compliance with primary standards would be by 1985. However, using estimates by A.D. Little, Inc. (*18, 19*), we have calculated that, assuming a 2% per annum growth in steel output, the maximum figure is some $36 billion, with a minimum of some $23 billion at 1978 prices. For zero growth the range would be $10 to 15 billion.

Efficiency and the Particulate Primary Standard

We have already observed that efficiency considerations require that dollar expenditures on the reduction in TSP concentrations should yield higher benefits than expenditures diverted elsewhere. More strictly, expenditure at the margin should yield the same benefit for the maximum health benefits to be achieved. One way of approaching this issue would be to estimate directly the benefits from reducing TSP levels and compare them with the costs estimated above. If the benefit exceeds the cost, the 75 μg/m³ standard would be justified in principle, although it would still be necessary to investigate whether still higher benefits could not be achieved by diverting the expenditure elsewhere. If the benefits are less than the cost, then, ideally, we would identify the level of TSP concentration at which benefits minus costs are maximized. This would be above 75 μg/m³ and, if benefits were found to be significantly less than costs, might even be near to or at concentration levels above those currently prevailing.

The problems with the direct approach are that we are unable, because of data limitations, to distribute the costs identified across TSP concentrations, i.e., we have an approximation of the total cost of compliance for the period from 1980 to 1985 but we have no idea of the functional relationship between TSP and abatement cost. Close inspection of the cost data confirms that it is not possible at present to determine this. Moreover, we have to bear in mind that two features of the primary standard can be varied: first, the standard itself and, second, the margin of safety. Ideally, we would like to know the money cost of the margin of safety. In the previous section we suggested that, if the "no effects" threshold is 130 μg/m³, as suggested by Holland and his colleagues (*16*) then the major part of the costs identified in that section must be regarded as the cost of the margin of safety. What we cannot say is precisely how much that cost is. We have no exact data to indicate what would happen to ambient concentrations of TSP in the relevant areas if the 1980-85 expenditures were not undertaken. New capital expenditures and the operating costs associated with them are not clearly associated with TSP levels in the current A. D. Little work (*18, 19*). Nor do we know what would happen if some of the operating costs associated with plant in-place at end 1979 were negated by closure of the control plant. This is a major data deficiency and we see no way in which it can be overcome. Here, certainly, there is scope for further research.

To underline what such research might reveal, consider Figure 1. This shows a benefit function and an abatement cost function. Both are hypothetical, save that we know that benefits cease at a level of 130 μg/m³. They are also speculative for

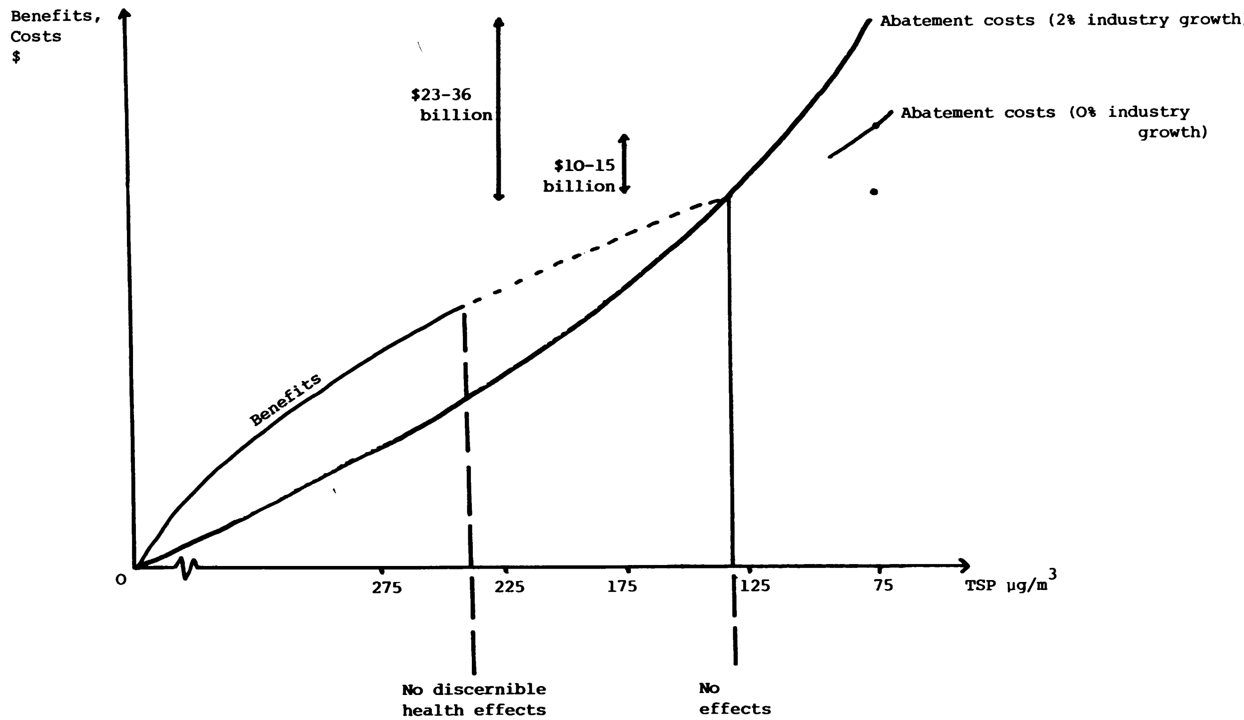

FIGURE 1. Benefits and costs of reductions in TSP.

the range 240 μg/m³ to 130 μg/m³ which is the range identified by Holland and his colleagues (*16*) as having possible TSP reduction benefits but in which those effects, if they exist, are not distinguishable from the effects of weather and other variables. What we can be certain of is that the abatement cost curve will continue rising throughout the range and at an increasing rate. As noted earlier, however, we have no idea of the precise functional form. Note that, whatever the costs of abatement, if the 130 μg/m³ "no effects" threshold is accepted as per Holland and his colleagues (*16*), all the extra expenditure incurred in securing compliance with the primary standard has no counterpart benefits. In terms of the efficiency principle, we are saying that this expenditure implies an infinite value of human life and suffering since we can identify no health gains from the extra expenditure. This is entirely consistent with saying that the primary standard is compatible with a zero risk plus "overkill" element in the equity approach. If some error is attached to the 130 μg/m³ threshold, i.e., if it is right within ±10%, then, at best, 10% of the extra abatement expenditures would be worthwhile in principle on the basis of insuring against possible adverse health effects as required by the 1977 Clean Air Act amendments.

Despite the very limited data and the problems of using the available cost data for our desired purposes, it is possible to engage in some other exercises to see what the 75 μg/m³ standard means and what the implied margin of safety of 42 to 55 μg/m³ means. (The figure of 42 is achieved by assuming some 10% statistical error attached to the 130 μg/m³ level and the figure of 55 by assuming it contains no error since that error is subsumed in the range 240 to 130 μg/m³.)

An Illustration Using the 1979 Wyoming Study

To illustrate the way in which a cost-benefit approach might be used, we compare the cost figure above with the benefit figure for reduced particulate emissions to be found in the 1979 study by Crocker et al. (*20*). This used a statistical regression approach similar to that of Lave and Seskin (*21*) but controlled for more variables. The only significant statistical relationship found for particulates was the claim that a 60% reduction in average particulate concentrations would reduce pneumonia deaths in urban areas by 13,000 per annum. To these physical results, a "value of human life" of $340,000 to $1 million was applied. (Clearly these values must include some allowance for associated morbidity as well. Indeed in any reference to a value of life in the rest of this paper, this should be read to embrace not only the value of life *per se* but also the associated morbidity.) The monetary health benefits were then some \$4.4–13.7 billion per annum (1978 prices).

The hypothetical 60% reduction is from a base of 102.3 $\mu g/m^3$ which would thus be to 40.9 $\mu g/m^3$, well below the primary standard under the Clean Air Act and, of course, implying that health effects are clearly discernible below that level. We refrain from comment on that for current purposes. Suppose then we calculate the implied lives saved for a reduction to 85 $\mu g/m^3$, since the 102.3 $\mu g/m^3$ appears to be an arithmetic mean in the Wyoming study. We therefore convert the 75 $\mu g/m^3$ geometric mean standard to an 85 $\mu g/m^3$ arithmetic mean standard. This would be a 17.3% reduction on the mean value assumed in the Wyoming study (it relates to an average for 1970). Given the linearity assumptions in the study we can then argue that 29% (17.3 divided by 0.6) of the alleged benefits would supposedly ensue. This would give us a figure of 29% of 13,000 lives p.a. which equals 3,748 lives. For a period of 20 years this comes to 74,967 lives saved. Recall that this is for all TSP emissions, not just those from the steel industry. We estimate that steel contributes 9% of TSP (*22*) so that 6,747 lives would be saved.

For the various costs estimated above we then have implied values of life as shown in Table 1.

Table 1.

Abatement cost (billion)	Implied value of life (6747 lives)
\$23-36	\$3,409,000-5,336,000
10-15	1,482,000-2,223,200

Thus, even if we were to accept the valuation and methodology of Crocker and his colleagues (*20*), at no stage does the implied value of a human life fall within the range of \$0.34–1.0 million used in that study. This is formally equivalent to saying that cost-benefit criteria do not justify further TSP control in the steel industry to the 75 $\mu g/m^3$ standard.

An Illustration Using Other Implied Values of Life

We also compared the abatement costs involved with the number of deaths deferred taking the Lave and Seskin (*21*) estimates as being correct and without questioning them. A move from 130 $\mu g/m^3$ to 75 $\mu g/m^3$ is a 42% reduction in TSP concentration. Taking one of Lave and Seskin's very high "elasticities" (the rate at which excess deaths fall for a 1% reduction in TSP) at 0.08 (i.e., mortality falls by 8% of the fall in pollution) we obtain a figure of 8% of 42% = 3.4% reduction in mortality. Applied to an overall estimate of mortality this gives a figure of some 64,387 lives "saved" per year from TSP reduction to the primary standard. Using our 9% TSP contribution-by-steel estimate, this would give some 5,795 lives per annum saved by enforcement of the standard. Over 15 years this suggests some 86,923 lives saved. The resulting "implied" values thus lie in the range \$110,000 to \$410,000.

Superficially, then, the exercise using the high Lave and Seskin "elasticity" looks far more favorable to the use of a standard of 75 $\mu g/m^3$. It requires acceptance of the Lave and Seskin estimates which, we observe, are not consistent with the epidemiological data reported by Holland and his colleagues (*16*). However, even if we take the Lave and Seskin figures, implied values found elsewhere in preventive and curative medicine (see Table 2) do not support such valuations, i.e., they are lower than the range reported above.

Table 2. Implied values of life in various health care policy areas.

Policy area	Implied value of life	Source
Pulmonary embolism	\$19,000	(*23*)
Renovascular disease	25,000	(*23*)
Heart attacks		(*24*)
Ambulance	6,000	—
Mobile coronary unit	8,300	—
Triage plus ambulance	27,000	—
Screening	46,000	—
Critically ill patients	24,000 (per year of life)	(*25*)
End-stage renal disease	24,000 (per year of life)	(*26*)

What emerges from this outline of a few case studies in the health sector are two important considerations. (1) While it is frequently difficult to compare "like with like," because of difficult base lines for costs, different time horizons, different types of output, etc., nonetheless it is clear that there is a wide range of values being attached to lives saved and years of life extended in decisionmaking on resource allocation in the health sector; (2) Some of the values emerging for programs which are not or at least are not widely available in the health sector are low compared to those likely to be implied by the analysis in this section of the costs and benefits of the proposed standards for TSP abatement, thereby suggesting, in the context of the cost-benefit approach, that resources would be better expended in these areas of health care than in TSP abatement.

Again, the mortality reduction which would follow from the cumulative introduction of various road safety measures has been reported (*27*). Thus, costs of approximately $18 billion over a 10-year period (at 1978 prices) would have forestalled 138,000 fatalities. On the most favorable estimate of TSP reduction benefits, 87,000 lives would be saved for a comparable sum of money. The TSP control expenditure is thus less cost-effective i.e., if it were to be pursued, there are many more efficient ways of saving life which ought to be implemented ahead of it.

Conclusions on Efficiency Approaches

Bearing in mind the deficiencies in the data that we have used, we have attempted to secure "most favorable" comparisons in cost-benefit terms for TSP reduction expenditures. By this we mean that we have made the case as favorable to TSP control as we could, by adopting high values taken from other studies or taking extreme assumptions such as a zero threshold.

We would propose that the rules of cost-benefit analysis for the rational allocation of resource within the economy have not been honored if the benefits obtained from TSP reduction are less than they would be if hypothetically spent elsewhere. That is what this paper has set out to show, and we argue that the weight of evidence favors the demonstration of this proposition.

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